

# DEVELOPMENT AND IMPLEMENTATION OF A VIRTUAL LABORATORY FOR TRAINING PROCESS IMPROVEMENT IN THE MECHANICS OF CONTINUOUS MEDIA

Rodrigo, B. G.<sup>1</sup>; G. Pulido, M D<sup>2</sup>.; Hernando-Mansilla, F<sup>3</sup>.; de Isidro-Gordejuela F<sup>3</sup>.; Castilla-Heredia I<sup>3</sup>.; Prieto-Muñoz, F.; Mosquera, JC<sup>4</sup>., Fernández-Ordoñez, D<sup>1</sup>

<sup>1</sup> Dpto. Ingeniería Civil: Tecnología de la Construcción. Universidad Politécnica de Madrid (UPM) (SPAIN)

<sup>2</sup> Instituto Eduardo Torroja Ciencias de la Construcción (IETcc). Consejo Superior de Investigaciones Científicas (CSIC) (SPAIN)

<sup>3</sup> Escuela Politécnica Superior de la Universidad San Pablo CEU (USP CEU) (SPAIN).

<sup>4</sup> Dpto. Mecánica de los medios continuos y teoría de las estructuras. Universidad Politécnica de Madrid (UPM) (SPAIN)

## Abstract

The project arises from the need to develop improved teaching methodologies in field of the mechanics of continuous media. The objective is to offer the student a learning process to acquire the necessary theoretical knowledge, cognitive skills and the responsibility and autonomy to professional development in this area. Traditionally the teaching of the concepts of these subjects was performed through lectures and laboratory practice. During these lessons the student's attitude was usually passive, and therefore their effectiveness was poor. The proposed methodology has already been successfully employed in universities like University Bochum, Germany, University the South Australia and aims to improve the effectiveness of knowledge acquisition through use by the student of a virtual laboratory. This laboratory allows to adapt the curricula and learning techniques to the European Higher Education and improve current learning processes in the University School of Public Works Engineers (EUITOP) of the Technical University of Madrid (UPM), due there are not laboratories in this specialization.

The virtual space is created using a software platform built on OpenSim, manages 3D virtual worlds, and, language LSL (Linden Scripting Language), which imprints specific powers to objects. The student or user can access this virtual world through their avatar (your character in the virtual world) and can perform practices within the space created for the purpose, at any time, just with computer with internet access and viewfinder.

The virtual laboratory has three partitions. The virtual meeting rooms, where the avatar can interact with peers, solve problems and exchange existing documentation in the virtual library. The interactive game room, where the avatar is has to resolve a number of issues in time. And the video room where students can watch instructional videos and receive group lessons. Each audiovisual interactive element is accompanied by explanations framing it within the area of knowledge and enables students to begin to acquire a vocabulary and practice of the profession for which they are being formed. Plane elasticity concepts are introduced from the tension and compression testing of test pieces of steel and concrete. The behavior of reticulated and articulated structures is reinforced by some interactive games and concepts of tension, compression, local and global buckling will by tests to break articulated structures. Pure bending concepts, simple and composite torsion will be studied by observing a flexible specimen. Earthquake resistant design of buildings will be checked by a laboratory test video.

In this project Technical University of Madrid collaborates, through an innovative educational project, with the Polytechnic School of Architecture at the Universidad San Pablo CEU and the Institute Eduardo Torroja (IETcc) of Scientific Research Council (CSIC)

Keywords: Virtual laboratory, mechanics of continuous media, learning space, engineering, information and communication technology (ICT).

# 1 INTRODUCTION

One of the highlighted features of engineering education is the combination of theoretical knowledge with practical experience. The formation, in conventional education, consists on lectures and exercises supplemented by lecture notes and textbooks, while the last comprises highly resource-demanding laboratory courses and usually is limited to a relatively small audience. Recent developments in the area of information and communication technology have improved education techniques. The importance of distance learning, based on modern Internet techniques, is increasing continuously. As a result, there is a need to create platforms to offer on-line courses and to work out systems. These platforms allow conducting experiments in distance learning supported by an audio-visual interface together with a collaboration tool to simulate a real laboratory environment.

One of the early virtual engineering laboratories developed by Elsherbeni *et al.* [1] was a visualization tool for microwaves and electronics. Others, including Montero-Hernández *et al.* [2] and Avouris *et al.* [3], pioneered computer-assisted laboratory courses to prepare students to the laboratory experience. The recent concept of virtual instrument has led to the application of new techniques in the field of measurement systems design. Moreover, in the main part on didactic laboratories, virtual instruments have replaced expensive and complicated real instruments. This has simplified the process of designing, setting and modernizing these laboratories [4]. Nedik *et al.* [5] in the research on "*remote laboratories versus virtual and real laboratories*" concluded that the main alternative to real laboratories are virtual laboratories. If they are well designed, they can offer a pedagogical advantage being able to show a better explanation of difficult theoretical concepts in the studied field. Mannix [6] documented the advantages of virtual labs. They are not equal in items of installation, development and maintenance costs as well as educational benefits. Virtual laboratories have been used with successful results in Structures as a fundamental learning tool. There are some interesting experiences in literature on reinforced concrete structures [7] and experiments on nonlinear structural dynamic analysis of multi-story buildings [8 to 10].

This paper presents the development of a teaching methodology in the field of mechanics of continuous media. This experience allows students to culminate their learning process acquiring the necessary theoretical knowledge, cognitive skills and the responsibility and autonomy for professional development in this area. The methodology is based on the creation of a virtual space, using a software platform built on OpenSim, which manages the 3D virtual world, and the LSL (Linden Scripting Language), which imprints specific powers to objects. The student or user can access this virtual world through their avatar (the character in the virtual world) and can navigate and interact with other users in virtual spaces as meeting rooms and video rooms. In these rooms, the avatar can display selected audiovisual productions. Besides simulation practices, it is also possible to interact realistically with external devices or instruments, thanks to a web service and an application developed in National Instruments Labview environment. Virtual labs offer a better accessibility to the student, better explanation of difficult concepts in the studied field and their cost is lower than in real laboratories [11].

Usually, courses on mechanics of continuous media have been based on lectures and laboratory practices. Student's attitude was generally passive during these lessons, so that the effectiveness was low. The problems solved in tutorials were very similar. Through a virtual laboratory, students will learn using a tool that is very close and familiar, solving problems in groups, under the supervision of a teacher, leaving a written and visual track that works as future reference. Through the virtual laboratory they will apply and improve the understanding of received theoretical information. This knowledge acquisition process is continuous during the course, making it a useful tool for the teacher to make a continuous student assessment. As a result of this methodology, we expect to confirm Anderson and Hashemi [12] conclusion. They analyzed the results of a virtual laboratory on Materials and Mechanics and concluded that students using virtual laboratory were better in making comparisons, analyzing large quantities of frequently conflicting data, integrating various findings and reaching a well-founded and verified conclusion. The statistical analysis carried out during the test semester indicates that students who use virtual lab show a more in-depth understanding of the course material.

We consider it important to create a virtual laboratory on the Mechanics of Continuous Media subjects due to the absence of a real laboratory and the impossibility to build one, because of a lack of space. Currently, there is also the need to have a simple mechanism for continuous evaluation of students reflecting personal effort and dedication, in classes where the number of students exceeds 80.

The objectives of the project are:

1. Improving the learning processes of knowledge of Continuous Media Mechanics fields through information technologies and communication technologies (ICT)
2. Creating a virtual laboratory infrastructure to compensate for a lack physical laboratory in the current teaching of the Faculty of Civil Engineering
3. Involving the student in the process of creation of educational material and therefore in the process of acquiring knowledge, skills, autonomy and responsibility.
4. Adapting curricula and learning techniques to the European Higher Education Area.

## 2 METHODOLOGY

The proposed laboratory has three partitions in the virtual space. In these partitions, the avatar can access a different activity.

1. **Room videos.** This partition is formatted as a classroom, so the teacher avatar can use this space to attend classes or student questions. Here the student avatar can view videos explaining the theory of elasticity, foundations, strength of materials and analysis of framework structures (Fig.1). Videos are based on laboratory tests where each of the concepts is presented and analyzed in its practical application.

The concepts shown and discussed in the videos are:

1. The different mechanical behaviour of materials, stress-strain curves, the elasticity and plasticity concepts
- 2 - The stress and deformation of linear elastic beams in bending stress: a) remarking the Bernoulli-Navier hypotheses, b) observing the differences between pure bending and simple bending stress (biaxial). The student learns the influence of the links in the buckling length.
- 3 - The behaviour of articulated structures. Following the results, students elaborate on concepts of compression stress, local buckling and overall buckling.
- 4 - The behaviour of cross-linked structures (gratin). It deeps into concepts of deformation and bending joints.
- 5 - The behaviour of structures subjected to earthquakes, introducing the concepts of earthquake resistant design of buildings.
- 6 - The behaviour of composite materials.

After viewing each of these videos, the student must answer a series of questions to help determining the degree of interest in the subject, the assimilation of concepts and the knowledge acquired.



Figure 1. View of video room partition in the laboratory virtual of the mechanics of continuous media

2. **Mechanics laboratory of continuous media.** The aim of this partition is allowing students to simulate the behaviour of a structure under different loading systems and analyze the concepts seen in the theoretical lessons. For this purpose, students can make and test different structures under different actions. MATLAB and SIMULINK simulations are performed so that the avatar can compare different structures under load or the same structure under different loads.
3. **Group work room.** Avatars in this room can share impressions, jointly or participate in interactive games and exchange or obtain literature of interest (Fig. 2). This room consists of a large screen where the student (avatar) can perform a number of interactive games to reinforce the concepts learned during the courses of the subject area of mechanics of continuous media.



Figure 2. View of group work room in the laboratory virtual of the mechanics of continuous media

Group workroom offers two activities:

a) Interactive games. In each module students have an initial brief introduction to the objectives of the experiment and a brief theory introduction with examples. Once the short introduction stage is completed, the experimental procedure begins.

These exercises are performed by the student in the virtual laboratory in a fixed time. Once the students answer the exercises, they get a percentage of correct answers. The educational material is created for the course and improved during project ensuring continuity in time and the constant updating of the tool in the learning process. This process of trial-and-error and discovery is a reflective process that stimulates students to think critically.

The eligible subjects are:

1. *Distribution of stresses in the section.* We analyze the distributions of stresses in different sections for identical internal forces applied to the center of gravity of that section
2. *Deformation of the section subjected to various stresses.* Given a beam subjected to different loading conditions, the student must choose, out of four possibilities, the one which better represents the expected deformation of the structural member.
3. *Determination of stress in the member.* Trusses are composed of straight members connected at their ends by hinged connections to form a stable configuration. When loads are applied to a truss only at the joints, forces are transmitted only in the direction of each of its members. That is, the members experience tension or compression forces. With this interactive game students have to determine which members work and the sense of the internal forces.
4. *Analysis of the member movements.* Crosslinked structures and flat trusses are analyzed. Students must determine the direction of movements at the nodes.

The proposed methodology allows the evaluation of the students' active participation in the virtual space. This indicator is assessed based on whether students have collaborated in the development of materials and have been involved in the resolution of questions of other

colleagues. It evaluates each student with a mark from 1 to 5 and computes the average of all of them.

b) Open library. In the room there is a space with a virtual library of educational material in open. The avatar can download or view information, share the doubts with peers and consultations with the teacher.

### **3 RESULTS**

The project is being implemented, so there are still no statistical results to determine the extent of impact of the virtual laboratory in the student learning process.

The way to evaluate the project will take place in base indicators listed below:

- 1 - Academic results of the term in January 2014 compared to previous years.
- 2 - Degree of student satisfaction compared to surveys in previous years.
- 3 - Percentage of students who used the tool and time spent.
- 4 - Active participation of students in the virtual space.

During the first half of 2013-2014, while teaching the subjects, there will be a more comprehensive assessment of the project's results. Currently, the only tangible result is the high interest showed by students, to collaborate actively in the creation of material to place in the virtual space. Therefore, a volunteer group of senior students is working in the Faculty of Civil Engineering (ETSIC).

### **4 CONCLUSIONS**

1. Virtual labs offer real advantages in engineering education and can supplement physical labs. Virtual labs can be an alternative to physical labs when such labs are unavailable because of lack of space or funds or equipment malfunction.
2. The virtual laboratory shows the potential to help the student in learning engineering concepts. We expect that the student quiz results taken immediately after they viewed the virtual experiment will confirm that the learning objectives are effective as a complementary tool.
3. Virtual Laboratory is a useful tool to teach, but educators must take care to ensure that pedagogy drives the development of technology tools and not the contrary. As Universities experience declining budgets and increased demand for all resources, technology may provide some efficiencies and economies. However, these technology tools should be student-centred and pedagogically based. Low maintenance costs make virtual labs an important tool in a situation in which laboratory funds (both material and consumables) are being cut substantially.
4. Digital libraries in development in this laboratory have the potential to share and to deliver high quality digital information
5. Further research will develop different interactive games in the Mechanics area as they stimulate students and increase a reflective process

### **ACKNOWLEDGEMENTS**

We thank Juan Alberto Paz- Curbera y Llovet for its large effort to boost virtual teaching in Engineering. He was coordinator of the educational innovation project "Development and implementation of a virtual laboratory are using information technology and communications to improve the learning process in mechanics of continuous media" and the "Master in Project Foundation Structures" at the Technical University of Madrid taught virtually in its entirety.

This study was possible thanks to the support of Educational Innovation Programme (Technical University of Madrid) in collaboration with Universidad San Pablo CEU.

## REFERENCES

- [1] Elsherbeni, A., Tew, M., and Mokaddam, A.(1995), Applying Multimedia Technology to Undergraduate Engineering Laboratories. *Computer Applications in Engineering Education*, 3(2).
- [2] Montero-Hernandez, O., Rugerio De La Rosa, A., Baez-Lopez, D., Alejos, R.,(1999). Power Lab: a Tool to Learn Electrical Machines and Power Electronics. *Computer Applications in Engineering Education*; 7(3).
- [3] Avouris, N. M., Tselios, N., and Tatakis, E. C.,(2001) Development and Evaluation of a Computer-Based Laboratory Teaching Tool, *Computer Applications in Engineering Education*. 9(1).
- [4] Rak, R.J., Godziemba-Maliszewski M., Majkowski A. 2006. A proposal of virtual laboratory structure IMTC 2006 – Instrumentation and Measurement Technology Conference 24-27 April 2006 Sorrento, Italy p847-850.
- [5] Nedic, Z, (2012) Demonstration of Collaborative Features of Remote Laboratory NetLab Remote Engineering and Virtual Instrumentation (REV), 2012 9th International Conference on. 4-6 July Bilbao, Spain
- [6] Mannix, M.,(2000). The Virtue of Virtual Labs, Prism Online, URL: <http://www.asee.org/prism/sept00/html/toolbox.cfm>
- [7] Jiang H., Kurama Y. C. and Fanella D.A., (2002) WWW-based virtual laboratories for reinforced concrete education. *Computer Applications in Engineering Education*. 10(4), p. 167–181.
- [8] Gao Y., Yang G., Spencer Jr. B. F., Lee G. C. (2005). Java-powered virtual laboratories for earthquake engineering education. *Computer Applications in Engineering Education*. 13(3), p. 200–212.
- [9] Kuester, F and Hutchinson T. C. (2007) A virtualized laboratory for earthquake engineering education. *Computer Applications in Engineering Education*. 15(1), p. 15–29.
- [10] Sim, S. H. Spencer Jr. B. F., Lee G. C. (2009) Virtual laboratory for experimental structural dynamics. *Computer Applications in Engineering Education*. 17(1), p. 80–88.
- [11] Nedic, Z.; Machotka, J.; Nafalski (2003), A.Remote laboratories versus virtual and real laboratories. *Frontiers in Education*, 2003. FIE 2003 33rd Annual (Volume:1)
- [12] Anderson E.E. and Hashemi J. (2006) Virtual Laboratories: Changing Engineering Education. *International Conference on Engineering Education*. July 23 – 28